Short Communication: Prepartum Photoperiod Effect on Milk Yield and Composition in Dairy Cows

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ABSTRACT

In a previous paper we analyzed the effects of day length, the daily change in day length, and heat load prevailing on test days, and on milk yield and composition of dairy cows in hot weather. For this analysis we used milk tests of three herds in Israel between 1994 and 1996. We used the same database to analyze the effects of the day length and the daily change in day length 3 wk prepartum. The prepartum day length effect was negatively related to milk yield and to milk fat and protein percentages. The daily change in day length was negative for milk yield and lactose percentage and positive for protein content and did not affect fat content. The difference of 4 h between the shortest and the longest day, plus the seasonal change in day length, accounted for the addition of 1.9 kg of milk/d for a cow calving after the shortest day compared with a cow calving after the longest day. The difference in milk composition between these two cows was estimated to be 0.27 and 0.08% of fat and protein, respectively.

(Key words: milk yield, milk composition, photoperiod, preparturition)

Abbreviation key: DC = daily change in day length (min/d) at the test day, DCP = daily change in day length (min/d) 21 d before parturition, DL = day length (h) at the test day, DLP = day length (h) 21 d before parturition, HL = heat load (index) at the test day.

INTRODUCTION

The seasonal effects of photoperiod and heat load on milk yield and composition of lactating cows in hot weather were reported previously (Aharoni et al., 1999). In that paper, we referred to the heat load (HL), day length (DL) and the daily change in day length (DC) during lactation. Recent evidence (Miller et al., 2000; Petitclerc et al., 1998) suggests that the DL prepartum affects the milk yield of cows in the subsequent lactation. Furthermore, this effect was negative, i.e., short days in the prepartum period were associated with increased milk yield thereafter, in contrast to the positive effects of DL and DC on lactating cows. The use of appropriate regression models to analyze large databases of milk test records in commercial herds enables detection of seasonal effects on milk composition, in addition to their effects on milk yield (Aharoni et al., 1999). Therefore, in the current report, we used the database from our previous study to test the effects of prepartum DL and DC on milk yield and composition in the subsequent lactation.

The database (Aharoni et al., 1999) comprised 28,029 milk test records of 2029 cows in three herds, collected in a 3-yr period, January 1994 to December 1996. Only records of less than 271 DIM were included to avoid the possible effect of stage of pregnancy on yield. Day length (h), DC (min/d), and HL (arbitrary index units) for each test day were calculated as described previously (Aharoni et al., 1999). The database included identification of each cow by cow ID, herd, year, lactation number, test date, DIM, milk yield (kg/d), and percentages of fat, protein and lactose in the milk, and the seasonal variables at the test date: DL, DC, and HL. To these, we added records of the prepartum day length (DLP, h) and daily change in the day length (DCP, min/d), which were calculated for a date that precedes parturition by 21 d.

We compared two regression models, the first (model 1) was used in the previous paper for the common analysis of the three herds, and the second (model 2) included the DLP and DCP variables.

The equation of the regression model was:

\[ Y_{ijklm} = A_i + Y_{Rj} + L_k + b_{1k} \times \text{DIM} + b_{2k} \times \text{DIM}^2 + b_{3k} \times \text{DC} + b_{4k} \times \text{DCP} + c_{1r} \times \text{HL} + c_{2r} \times \text{HL}^2 + c_{3r} \times \text{DIM} \times \text{HL} + c_{4r} \times \text{DIM}^2 \times \text{HL} + c_{5r} \times \text{DC} \times \text{HL} + c_{6r} \times \text{DCP} \times \text{HL} + d_{1r} \times \text{MY} + e \]

where:

\[ A_i, Y_{Rj}, L_k \]
\[ b_{1k}, b_{2k}, b_{3k}, b_{4k}, c_{1r}, c_{2r}, c_{3r}, c_{4r}, c_{5r}, c_{6r}, d_{1r}, e \]

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Table 1. Seasonal effects on milk yield. Common photoperiod, and separate in-herd effects of heat load on milk and covariate-adjusted percentages of milk fat, protein and lactose. Model 2 (M2), which included effects of the day length and daily change in day length 21 d before parturition, is compared with model 1 (M1), which did not include these effects.

<table>
<thead>
<tr>
<th>Effects</th>
<th>Milk yield, kg/d</th>
<th>% Fat in milk</th>
<th>% Protein in milk</th>
<th>% Lactose in milk</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M1</td>
<td>M2</td>
<td>M1</td>
<td>M2</td>
</tr>
<tr>
<td>DL^a</td>
<td>Value</td>
<td>-0.394</td>
<td>0.372</td>
<td>-0.0189</td>
</tr>
<tr>
<td>t Value</td>
<td>13.3</td>
<td>12.5</td>
<td>-5.34</td>
<td>-6.19</td>
</tr>
<tr>
<td>P</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
</tr>
<tr>
<td>DC^b</td>
<td>Value</td>
<td>0.567</td>
<td>0.559</td>
<td>-0.0209</td>
</tr>
<tr>
<td>t Value</td>
<td>13.2</td>
<td>13.0</td>
<td>-4.08</td>
<td>-4.25</td>
</tr>
<tr>
<td>P</td>
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<td>***</td>
<td>***</td>
<td>***</td>
</tr>
<tr>
<td>DLP^c</td>
<td>Value</td>
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<td>-0.0634</td>
<td>-0.0156</td>
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<tr>
<td>t Value</td>
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<td>***</td>
<td>***</td>
<td>***</td>
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<tr>
<td>DCP^d</td>
<td>Value</td>
<td>-0.089</td>
<td>0.0037</td>
<td>0.0088</td>
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<td>***</td>
<td>***</td>
<td>***</td>
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<td>HL1^e</td>
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<tr>
<td>t Value</td>
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<td>-11.7</td>
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<tr>
<td>P</td>
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<td>HL2^e</td>
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<tr>
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<td>***</td>
</tr>
<tr>
<td>HL3^e</td>
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<td>-14.0</td>
</tr>
<tr>
<td>P</td>
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<td>***</td>
<td>***</td>
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</tr>
</tbody>
</table>

^aDay length, h.
^bDaily change in day length, min/d.
^cDay length 21 d before the last parturition.
^dDaily change in day length 21 d prior to the last parturition.
^eHeat load index in each of herds 1, 2, and 3.

\[
Y = \text{daily milk yield or percentages of fat, protein, and lactose of cow } i \text{ that calved at year } j \text{ on lactation } k, \text{ at milk test } l, \text{ in herd } m.
\]

\[
A = \text{absorbing effect of the individual cow } i
\]

\[
YR = \text{effect of year } j
\]

\[
L = \text{effect of lactation grade (} k = 1, 2, 3 \text{ or } 4 \text{ for } L 1 \text{ through } 4, \text{ respectively, and } k = 5 \text{ for } L = 5+\)
\]

\[
\text{DIM} = \text{days in milk}
\]

\[
\text{DL} = \text{day length (h)}
\]

\[
\text{DC} = \text{daily changes of day length (min/d)}
\]

\[
\text{DLP} = \text{day length (h) 21 d prepartum (only in Model 2)}
\]

\[
\text{DCP} = \text{daily change in day length (min/d) 21 d prepartum (only in Model 2)}
\]

\[
\text{HL} = \text{heat load index}
\]

\[
\text{MY} = \text{milk yield, when } Y \text{ is fat, protein or lactose percentages}
\]

\[
b_{1,2,3,4,k} = \text{regression coefficients for lactation } k
\]

\[
c_{1,2,3,4,5} = \text{regression coefficients for seasonal effects}
\]

\[
d = \text{regression coefficient for milk yield}
\]

\[
e = \text{random residual effect}
\]

\[H_m = \text{the herd effect, and } c_3 \text{ was the regression coefficient for HL in herd } m. \text{ The seasonal effects on milk yield and composition, which were estimated by model 2, are compared to those estimated by model 1 in Table 1. In conclusion, all the effects that were significant by model 1 were significant by model 2 as well, with values and probability measures very similar to those of model 1. The DLP was estimated by model 2 to have a very significant (} P < 0.001\text{) negative effect on milk yield, with good agreement with the results reported by Petitclerc et al. (1998). Miller et al. (2000) reported an addition of 3.2 kg of milk/d in the first 16 wk after parturition, for short-day cows, compared with long-day cows, as a response to a difference of 8 h in day length between the groups. Our estimation of a difference of 1.9 kg of milk/d between winter and sum-}
\]
mer calving cow refers to 270 d rather than 112 d, and to combined effects of DLP and DCP for an annual amplitude of only 4 h in day length between winter and summer. Therefore, we suggest that our estimation agrees with this report. Fat and protein, but not lactose percentage in milk were also negatively related to DLP ($P < 0.001$). Milk yield ($P < 0.05$), and lactose percentage ($P < 0.001$) were negatively affected, whereas protein percentage was positively affected ($P < 0.001$), and fat percentage was not affected by DCP. The effects of the prepartum DL and DC on milk yield were in contrast to their effect at the test day, which were both positive. On the other hand, the effects of DL and DC on fat and protein percentage were negative whether before parturition or at the test day. The combined effect of DL and DC, either for the milking period or for the prepartum period, on milk yield and composition may be described as an annual sinusoid response for each of the dependent variables. On this sinusoid, the peak date (the date of the maximum positive response) can be detected.

Table 2 presents the estimated peak dates of milk yield and composition for either milking or prepartum cows. Peak dates for milk yield differed by approximately 6 mo between lactating and prepartum cows, whereas those for fat and protein percentages were similar for the two states. The difference for the dates of the peak effect on lactose differed by approximately 3 mo between the two states. The contrast in response of milk yield to photoperiod between milking and prepartum cows on one hand, and the similarity in responses of milk composition between these states, may suggest different pathways in the response of yield and of composition. Long days are associated with elevated prolactin (Miller et al., 2000; Petitclerc et al., 1998). Still the response of milk yield to these elevated hormone levels was positive when it occurred in lactation, and negative when it occurred before parturition. Therefore, it is suggested that the difference in the response of milk and milk components to the photoperiod should be considered in factors that are affected by the hormone level.

The difference in day length between the shortest and the longest day in Israel (latitude of 32°) is approximately 4 h. Such a difference could account for an additional 1.9 kg of milk/d, 0.27% fat, and 0.08% protein for a cow calving in January, compared with a cow calving in July, in the first 270 d of the lactation. The summer calving cow is estimated to have 0.03% more lactose than a winter calving cow.

In contrast to manipulation of the day length during lactation, which will induce adverse effects on milk yield and milk composition, decreased day length during the prepartum period will result in increased milk yield and improved milk content in the subsequent lactation. Because this induction period is relatively short, it could be beneficial to keep prepartum cows in a short-day regimen.

REFERENCES